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Power Enhancement of a Rubidium Vapor Laser with a Master Oscillator Power Amplifier (Postprint)

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Power enhancement of a Rubidium vapor laser with a master oscillator power amplifier

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Abstract: A master oscillator power amplifier (MOPA) with variable amplifier gain lengths was built to demonstrate power enhancement of an alkali vapor laser. A small signal gain of 0.91 / cm for two different gain lengths was observed. For a 2 cm long amplifier gain length an amplification of 7.9 dB was observed.

OCIS codes: (140.1340) Atomic gas lasers; (140.3280) Laser amplifiers.

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1. Introduction

The concept of alkali lasers was first suggested by Schalow and Townes in the late 1950s [1]. In the 1970s photo-dissociation of several of the alkali salts produced lasers with wavelengths ranging from the visible to the far infrared [2-4]. Thirty years later, diode-pumped alkali lasers

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(DPAL) started rapidly gaining attention as highly-efficient lasers as well as brightness converters. These systems partly owe their high efficiencies due to the very small energy differences between the pump and lasing levels (2% for Rb and 5% for Cs). Due to recent technological advances in the field of solid state lasers, direct diode pumping has provided the efficient, yet compact method for excitation.

Since the initial formulation of the DPAL concept in 2003 by Krupke, et al. [5-7], several groups have conducted various experiments in this field with very promising results. For the initial experiments, a Ti:Sapphire surrogate was used to pump the pressure broadened absorption transition of the alkali species. Optical slope efficiencies of 54% for Rb and 59% for Cs with respect to absorbed pump power were reported [5,7]. In 2006, Ehrenreich et al. presented a narrow-banded (~ 1 MHz) diode pumped Cs laser with a slope efficiency exceeding 80% [8]. In 2006, Page et al. reported on the first DPAL system pumped with a multimode diode array [9]. Although optical efficiencies were lower, the radiance of the output laser was still 2000 times greater than the pump. Wang et al. produced a Cs laser using a Volume Bragg Grating coupled laser diode array and in 2007 increased the output power to several watts [10,11]. In 2007, Perschbacher et al. reported the development of a Rb DPAL with a slope efficiency of ~70% [12]. During the last year Zhanadov reported output powers for Cs of 10W and 18W for Rb using diode bars that were narrowed with an external diffraction grating [13-15]. Wu et.al. reported the results of Rb DPAL systems that only use helium for both broadening and relaxation in order to mitigate the problems that are associated with photothermal decomposition of the hydrocarbons used in many systems [16]. To date, to increase the power of alkali laser systems, higher intensity pumping of the gain medium has been used. However, there is a critical limit that can be achieved on these smaller scale systems due to decomposition of the gain medium due to excess thermal loading. One way to mitigate this problem is to use an amplifier or an amplifier chain. As demonstrated with solid state lasers this is a possible way to increase system power loading while alleviating the thermal management issues of the laser by spreading the heat out over several pieces of gain medium.

2. Experimental setup

The optically pumped alkali laser MOPA experiments were conducted using the setup outlined in Fig. 1. The output from a $Nd:YVO_4$ (Coherent Verdi-18) pumped Ti:Sapphire laser (Coherent MBR-01) was split approximately 4:1. The total output of the Ti:Sapphire

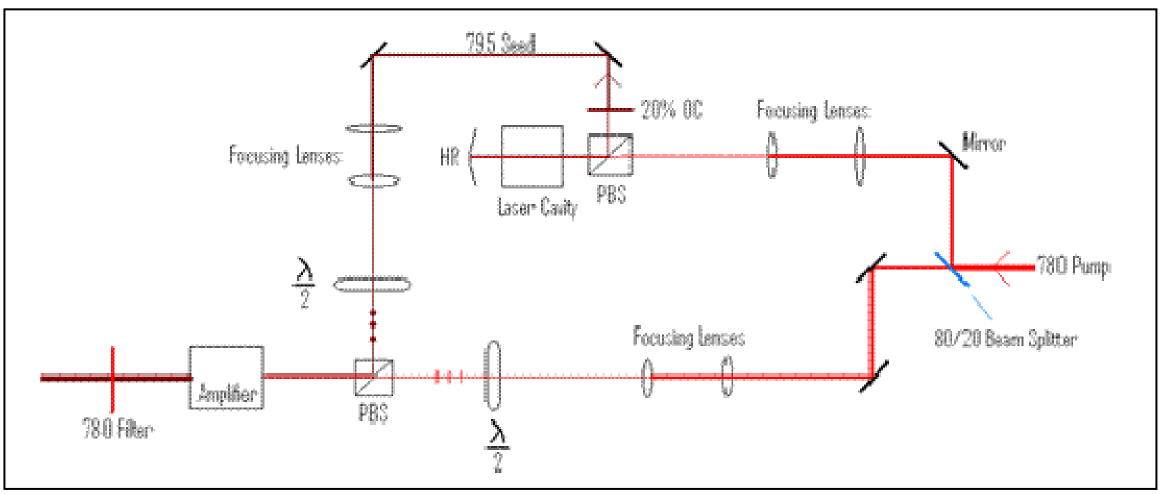

Fig 1. Optical setup for alkali laser MOPA

beam was ~3 Watts with an 8 GHz spectral bandwidth and tuned to the 780 nm D2 transition of Rb. Approximately six hundred milliwatts of the 780 nm light was directed into the alkali oscillator with the rest going to the amplifier path. The 795nm oscillator radiation was produced by setting up a rubidium alkali vapor laser as shown in Fig.1. The oscillator laser was built using an L-shaped configuration, as previously demonstrated in the literature, with a curved high reflector (~99.5% Reflectance, 20 cm radius of curvature, Lattice Electro-Optics) and a 20% reflective flat output coupler (Lattice Electro-Optics). The gain medium was a 2.5 cm long vapor cell (Triad Inc.) containing Rb metal and 450 torr of ethane. The number density of Rb in the gas phase was controlled by heating the vapor cell. For these experiments the temperature was maintained at ~ 105° C corresponding to a density of 6.6×10^{12} atoms/cc. A polarizing beam splitting cube was used to pass the pump beam into the gas cell while lasing on the orthogonal polarization. Approximately 50 mW of 795 nm radiation was produced with this configuration. The oscillator beam was directed through a set of lenses where the beam was focused and recollimated to a diameter of 0.50 mm. The beam was then passed through a second half wave plate and directed into the amplifier cell with another polarizing beam splitting cube. The latter half wave plate was used to adjust the amount of oscillator light entering the amplifier cell. The Rb amplifier consisted of another gain cell also containing Rb metal and 450 torr of ethane. The heater block used was large enough to accommodate various length cells. For these experiments, a 1.5 and 2.0 cm long cell were used. The amplifier was pumped with remaining 2.4 Watts of power from the Ti:Sapphire after being focused and recollimated to a spot size of ~0.65 mm. The residual 780 nm light was blocked from the power meter using a 780 nm long pass filter. (Semrock LP780). The experiments were conducted by measuring the intensity of 795 nm light before and after the amplifier. The oscillator intensity was varied from ~10 mW to 50 mW for both size amplifier cells and analyzed to determine the small signal gain observed.

3. Results

The results for the Rb DPAL MOPA experiments are shown in Fig. 2. The power in vs. power out for both gain lengths (1.5 cm and 2.0 cm) as well as the fit to determine the small signal gain coefficient are presented. For the experiments, a maximum intensity of ~ 25W / cm^2 of 795 nm oscillator light was used. Do to these small intensities the small signal gain (ssg) approximation:

$$\frac{P_{out}}{\pi r^2} = \frac{P_{in}}{\pi r^2} \times e^{(\alpha L)} \tag{1}$$

where P_{out} and P_{in} are the output and input powers, L is the path length, and α is the unsaturated gain coefficient was used for determining the gain coefficient of the amplifiers. Because the spot size (πr^2) for both the input and output 795 nm beam was the same it was merely factored out of the equation. The value for α for both length amplifiers was determined to be .91(1) / cm. This corresponds to an amplification of 5.9dB for the 1.5 cm cell and 7.9dB for the 2.0 cm cell. The authors believe that higher gains could easily be achieved by better matching the oscillator and amplifier spot sizes in the gain medium. The maximum extraction efficiency (power extracted / power in) for the amplifier experiments was 14%. This is lower than the 54% optical to optical efficiency that was achieved when all the radiation was directed into the oscillator. This result is not unexpected because the intensity of the master oscillator was purposely left low as to not cause saturation of the amplifier in order to determine the values of α.

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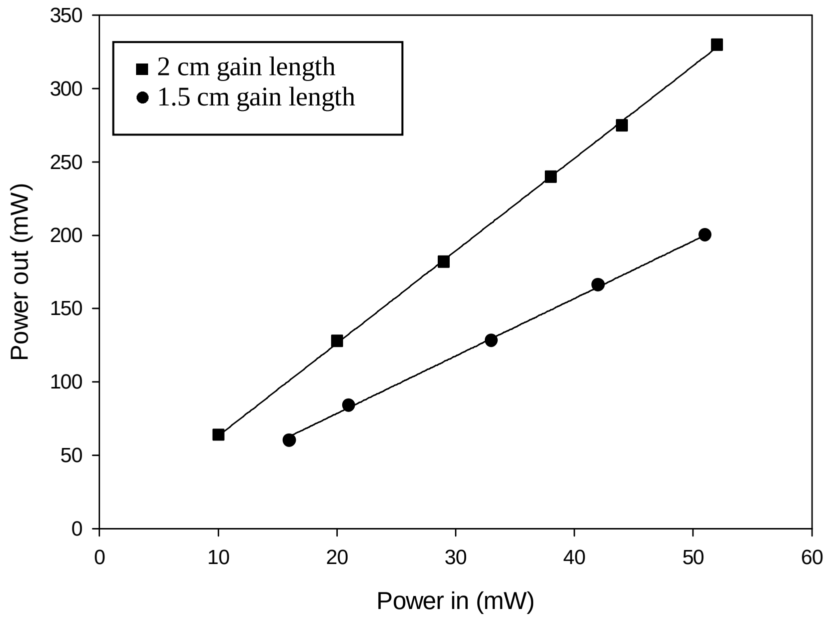

Fig 2. Plots of power in vs. power out of the alkali amplifier for two lengths of gain medium.

4. Conclusions

In conclusion power enhancement of a DPAL system utilizing an amplifier has been demonstrated. Relatively high gains with small gain lengths have been achieved. More importantly, the gain is not so high as to have parasitics such as amplified spontaneous emission become detrimental to laser performance.

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